Design and results of a biological feedback monitoring programme

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Concept et résultat d'enregistrement de données biologiques

Entwurf und Ergebnisse eines biologischen Rückkopplungsüberwachungsprogramme

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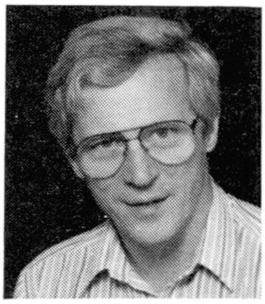

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SUMMARY

An Environmental Impact Assessment of the construction of the Great Belt Link (Denmark) showed that construction activities might have adverse impact on the marine environment. Therefore, a monitoring programme designed to quantify and control these effects was started in 1989. The programme comprises a new feedback principle implying mitigating actions to be taken by contractors if the biological effects exceed limits stipulated in the Environmental Impact Assessment. The design of the programme was based on the recommendations made by an international panel of environmental experts. The paper presents the results and discusses the relevance of the feedback principle.

Concept et résultat d'enregistrement de données biologiques

Résumé

L'étude de l'impact sur l'environnement de la liaison du Great Belt a montré que les activités de construction pourraient avoir un effet négatif sur l'environnement marin. Un programme d'enregistrement destiné à quantifier et à contrôler ces effets a débuté en 1989. Le programme comprend un nouveau principe d'enregistrement entraînant des mesures à prendre par les entrepreneurs si les effets biologiques dépassent certaines limites fixées. Le programme a été réalisé sur la base de recommandations d'un groupe d'experts internationaux de l'environnement. Les résultats sont passés en revue et le principe de rétroaction est discuté.

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Zusammenfassung

Eine Abschätzung der Umweltfolgen der Konstruktion der Grossen-Belt-Verbindung zeigte, dass Bautätigkeiten einen Einfluss auf die Meeresökologie haben könnten. Deswegen wurde 1989 ein Ueberwachungsprogramm gestartet, das entworfen wurde, um die Wirkungen zu quantifizieren und zu kontrollieren. Das Programmm umfasst ein neues Rückkopplungsprinzip, das Abhilfemassnahmen seitens der Baufirmen vorsieht, wenn die biologischen Auswirkungen die in der Umweltverträglichkeitsprüfung gesetzten Grenzen überschreiten. Der Programmentwurf gründete auf den Empfehlungen eines internationalen Fachkreises von Umweltexperten. Der Artikel präsentiert die Ergebnisse und diskutiert die Bedeutung des Rückkoppelungsprinzips.

1 INTRODUCTION

Specific requirement regarding the marine environment were stipulated by the act on the Great Belt link. To comply with these requirements A/S Storebæltsforbindelsen (the company to which has been established to construct and run the link) has established a comprehensive environmental programme [1].

To *neutralize* a potential impact on the *Baltic Sea* - as required by the act - the design has been greatly modified and mitigating actions have been taken in accordance with the result of hydrographic modelling [2].

To *minimize* environmental impact in the *near field,* ecological mapping, environmental impact assessments, baseline investigations and biological monitoring have been carried out. This paper describes the handling of the near field environment with emphasis on the biological monitoring programme.

2 INTERACTIONS BETWEEN ENVIRONMENTAL AND ENGINEERING ACTIVITIES

The construction work and the monitoring of possible associated effects on the marine environment in the near-field of the constructions site in Storebælt were initiated in 1989.

The monitoring programme is the last in a series of activities which are necessary for the successful handling of the biological effects in the near-by marine environment. The scheme shown in Fig. 1 emphasize the close interaction between the traditional engineering activities and the environmental activities.

It is the *general* experience from the Great Belt link project that environmental issues should be addressed early in the planning process. The possibilities for mitigating actions are progressively reduced as the planning and the construction process proceeds.

In *particular,* it is important to define and include the environmental requirements to the construction work in the tender documents in order to minimize the impact from the construction phase.

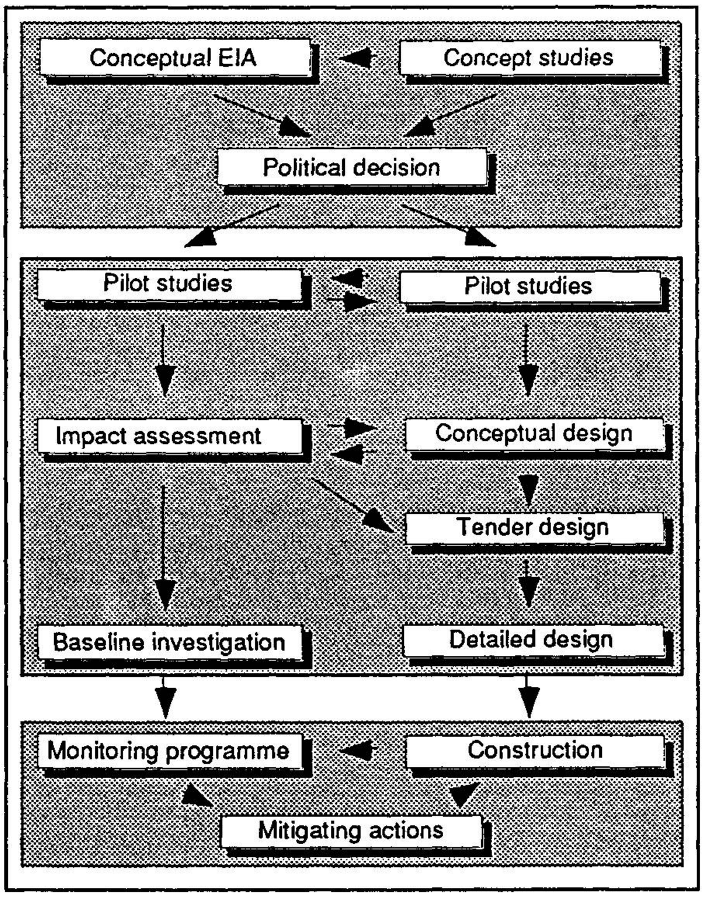

Fig. 1 Interaction between environmental and engineering activities.

3 DEFINITION OF MONITORING PROGRAMME

3.1 Objectives

The objectives of the biological monitoring programme are:

- to assess biological effects which can be used to initiate *feed back* loops whereby the construction process may be altered to mitigate environmental damage;
- to assess the extent and character of other possible adverse environmental effects arisen from the activities;
- to provide adequate environmental information to respond to public interest and settle possible issues.

3.2 Feedback Monitoring

Biological monitoring with feedback possibilities is a totally new concept, which has not previously been demonstrated to function in practise. The basic idea is that unacceptable changes in the environment caused by construction activities can be defined in terms of biological variables, and that the exceeding of the prefixed limit can lead to changes in construction activities which mitigate the adverse effects.

Three biological events have been chosen as important elements for the feedback monitoring:

- wintering eider ducks,
- spring spawning herring, and
- phytoplankton blooms.

These elements have been chosen for the reason that they may be affected by the construction activities at distances beyond the near-field area.

3.3 Key Biological Variables

In addition to the feedback parameters a number of other key biological variables have been selected on the basis that these are significant ecological components of the Great Belt marine ecosystems, and that effects of construction can be quantified reliably. The key biological variables are:

- eelgrass,
- kelp,
- mussels, and
- soft bottom fauna.

The use of key biological variables illustrates two other important principles of the monitoring programme:

- All parameters can be quantified;
- Falsifiable hypotheses have been established; some of these are conditional and will only be investigated when finding a significant effect in the first hypothesis.

4 ENVIRONMENTAL EFFECTS OF THE CONSTRUCTION ACTIVITIES

4.1 Ecological Mapping

As a basis for the Environmental Impact Assessment (EIA) and the definition of the monitoring programme the marine ecology of the Great Belt has been mapped prior to the start of the construction work (Fig. 2). The mapping was performed using diver operated video equipment, sediment and bottom fauna sampling equipment and fishing gear.

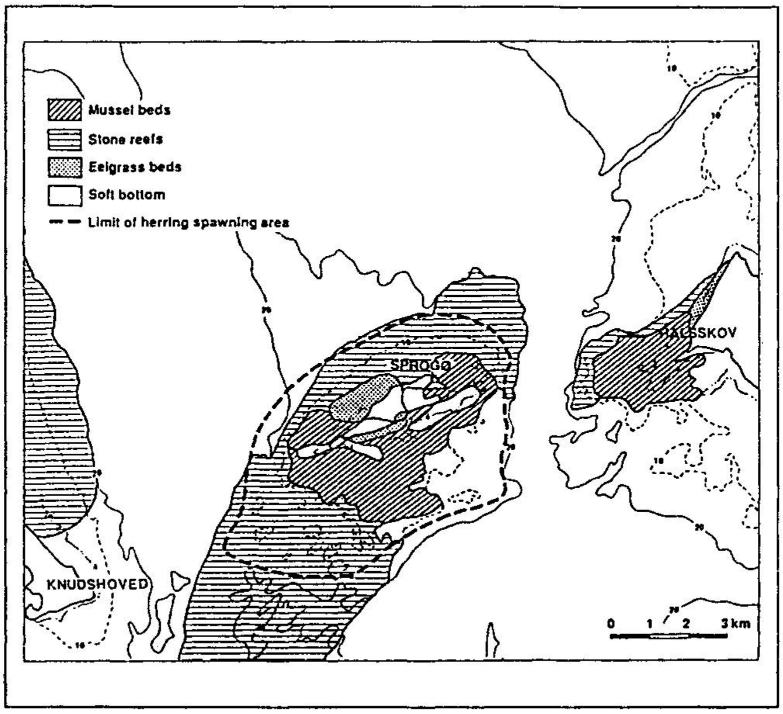

Fig. 2 Marine biotopes in the Great Belt

The area accommodates several areas of high ecological interest:

- *Herring spawning:* The area around Sprogø is used as spawning area for spring spawning herring.
- *Eiders/Mussel:* The area around Sprogø holds large flocks of wintering eider ducks gathering from great parts of northern Europe. The number of birds may in some winters reach figures of around 100,000. The eiders feed on the rich mussel beds in the area. The eiders are the main reason for the area being declared an EEC bird protection area.
- *Stone reefs:* Stone reefs are rich biotopes which are important as fish spawning and nursery areas and as feeding grounds for adult fish.

4.2 Environmental Impact Assessment

The conceptual EIA performed in 1988 [3] was upgraded in 1990 to a full EIA in 1989 [4]. A revised EIA [5] has since been prepared in order to allow for much higher dredging spill rates than anticipated in the first EIA.

The main environmental effects are related to the reclamation and dredging activities. The major part of the dredging activities concerns the dredging of reefs with the purpose of facilitating the flow of water to and from the Baltic Sea. This illustrates the dilemma between mitigating environmental effects in the far field (the Baltic Sea) and the near field (the Great Belt): The greater the effort to achieve the "zero solution" [2] for the Baltic Sea, the greater the environmental damage in the Great Belt.

In addition to direct destruction of habitats by dredging and reclamation the effects are related to the release and sedimentation of particles during dredging; the calculated sedimentation shown in Fig. 3 gives an indication of the intensity of this impact.

The main environmental effects predicted by the EIA and now partly verified by the monitoring programme (see later) listed below.

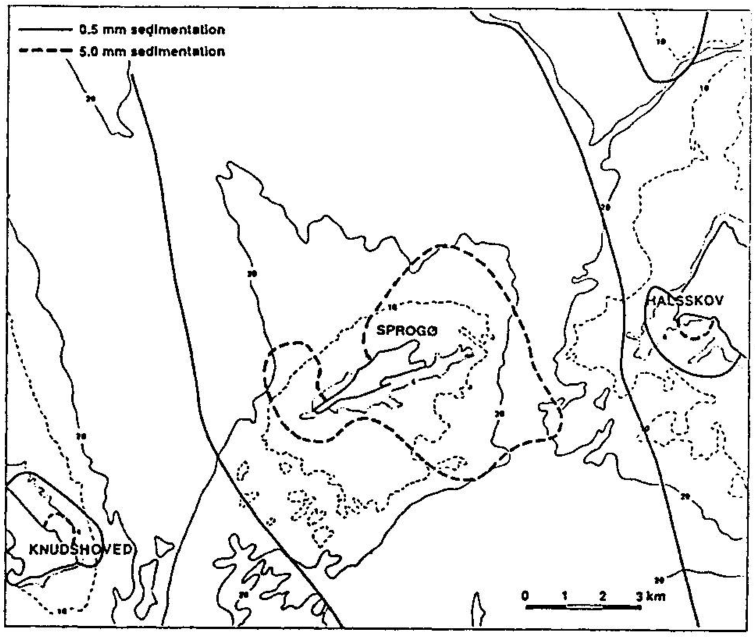

Fig. 3 Predicted sedimentation from dredging activities.

Short term effects (<10 years):

- Reduction of *mussel biomass* by x% due to reclamation, lee effects and smothering. It is estimated that the carrying capacity of the mussel beds as feed for *eider ducks* is reduced correspondingly.
- Decrease in macro *vegetation* on stone reefs by 30-40%.
- Decrease in area used as *herring spawning areas* by 20%.
- Change in composition of local *soft bottom fauna* communities due to smothering and anoxic conditions.

Long term effects (10+ years):

- A possible decrease in population size of wintering eiders and other diving ducks which feed on mussels;
- An increase in the area of eelgrass beds due to lee effects;
- A possible reduction of the area of herring spawning grounds;
- An incomplete recovery of perennial species of algae at stone reefs and eelgrass beds.

5 RESULTS OF MONITORING PROGRAMME

5.1 Overview

The biological monitoring programme was initiated in 1989 and it is now possible to assert some of the short term effects. Some effects are insignificant in relation to the regional ecology, e.g. the release of nutrients from suspended sediment material and the release of oxygen consuming substances.

Other effects may prove to have serious consequences, e.g. the effects of suspended sediment material on mussel beds and - ultimately - on the eider duck population as described below.

5.2 Effects on Mussel Beds and Eider Ducks

The monitoring of the conditions of the mussels beds along the alignment have shown a dramatic decrease in the population density (individuals/m^2) around Sprogø (i.e. close to the dredging activities); at other stations at greater distance (Halskov rev) a similar decrease could not be observed [6] (Fig. 4). Analysis of the development of the size distribution of the remaining individuals at the affected stations indicate that the decrease is caused by unsuccessful recruitment of young individuals. (Young individuals are recruited from swimming larvae which settle on the bottom; the larvae and newly settled juveniles are more susceptible to damages from smothering).

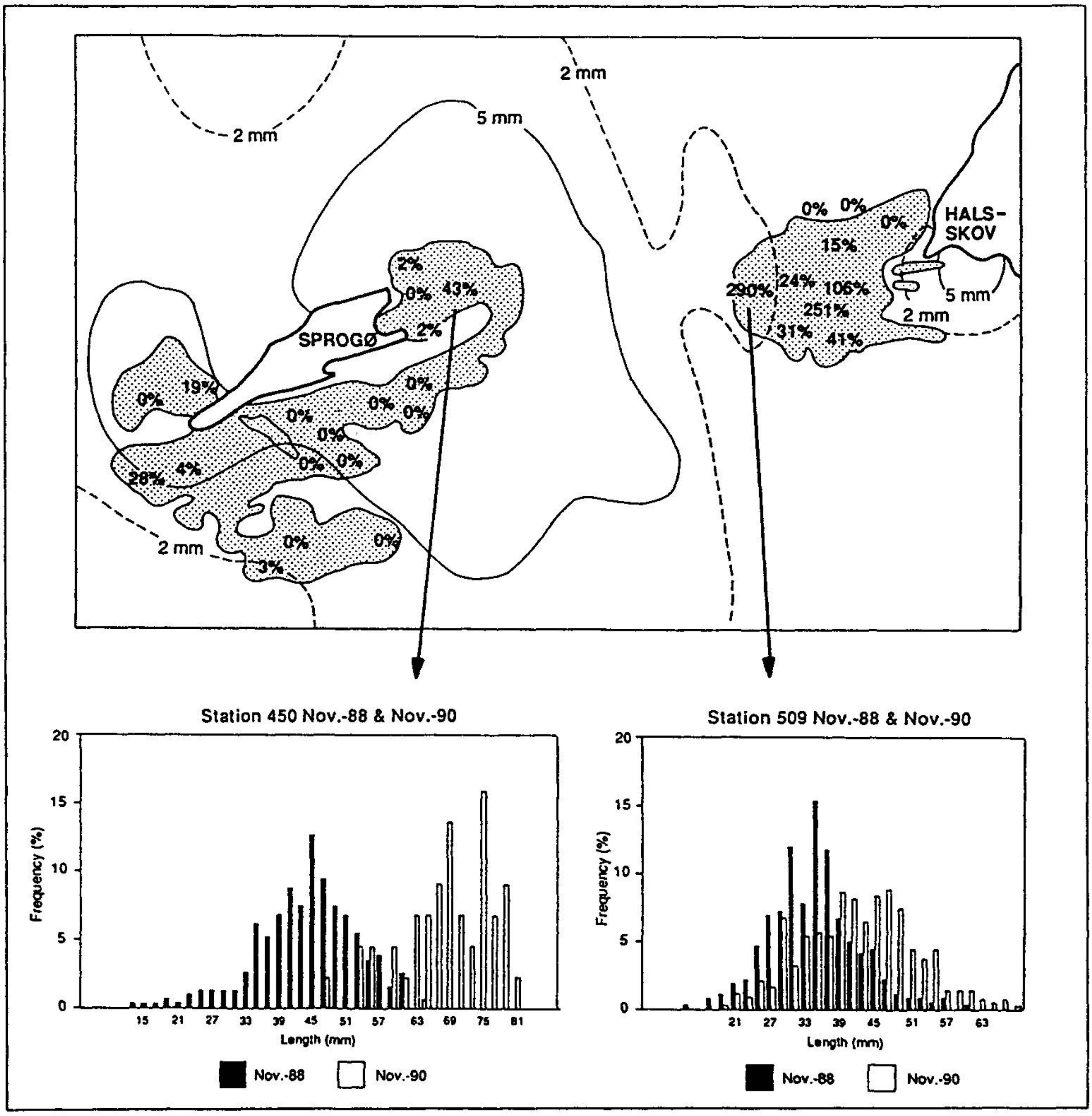

Fig. 4 Reduction in mussel population density and recruitment. *Above:* Population density in November 1990 relative to November 1988 in %. *Bottom left:* Typical shift in size distribution at station with decrease in population density. *Bottom right:* Typical size distribution from *Halskov rev* stations where little or no impact has been assessed.

The monitoring programme has also shown that the predators (mainly eiders and sea stars) during winter consume mussels corresponding to the production of one year [7]. It may therefore be assumed that the carrying capacity of the area for eiders has been reduced and that part of the eider population will be forced to find other wintering areas. Preliminary results from the winter 90/91 strongly suggest that this is the case: the number of eider around Sprogø have been drastic reduced and seemingly the eiders have moved to other locations in the Danish waters where an increase in numbers has been recorded [8].

6 CONCLUSION

The results and the experience from the biological monitoring programme so far have indicated that it is possible to assess the environmental impact from such projects, and to some extent limit the effects by mitigating actions.

However, some points are crucial for the possible applicability of the feedback principle:

- The monitoring programme must be based on a comprehensive baseline study and an impact assessment which enable the definition of precise and realistic limits relevant to the environment in question, which can release mitigating actions;
- Environmental considerations which ensure that a precautionary principle is introduced must be involved prior to the planning of the construction and the elaboration of tender material;
- All involved parties must have commitment to following the precautionary principle, be it (client, contractor, authorities, etc.);
- The monitoring programme must include a sufficiently fine grid - in time and space - in order precisely enough to demonstrate the transgression of feedback limits;
- The results of the monitoring programme must appear at intervals much shorter than and the time steps in the planning and progression of the construction work.

The present results of the biological monitoring programme in connection with the construction of the Great Belt Link indicate that a monitoring programme based on such principle may be drawn up, but so far none of the above critical items have been fully achieved.

ACKNOWLEDGEMENT

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